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Advances in Hydrogen Refuelling Stations

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Hydrogen-powered vehicles represent a promising solution to reduce overall green house gas emissions and ensure sustainable mobility.

Car manufacturers are developing prototypes with improved performances, more reliability and autonomy proving the viability of advanced technology vehicles. In parallel, the hydrogen infrastructure has to evolve to meet real-world demands and provide the required filling stations network that will enable the users to refill their cars, buses or scooters …

Air Liquide is a global leader in hydrogen fuelling and infrastructure. It has manufactured and installed more than 40 hydrogen fuelling stations in different countries, working jointly with leading vehicles manufacturers in order to design and build the future generation of filling stations.

Figure 1

These advanced stations should be able to perform fast filling on any type of vehicle.

As of today, temperature increase during filling has been causing many concerns and has prevented “blind” filling like what is performed with gasoline stations.

This paper presents innovative solutions developed by Air Liquide group to solve this issue and also to perform filling without communication, hence simplifying a lot the process. Combining modeling and advanced process control, these solutions enable to match the customer's requirements and specifications while ensuring quality and safety in the filling process. The path is now opened to moving from prototypes to industrialization.

The first step consists in implementing a control strategy to transfer hydrogen within vehicle tank taking into account the constraints given by the customer. Control scheme should enable to keep the temperature of the hydrogen inside the vehicle tank under maximum safety level while optimizing the refuelling time.

The control strategy has been built on the basis of dynamic simulations of a standard hydrogen station under Matlab/Simulink. A critical device to characterize was the actuator: at such level of pressure (above 800 bars), linear behaviour of the actuator is no longer guaranteed hence impacting highly the dynamical efficiency of the control scheme.

The specified advanced control scheme enabled Air Liquide to perform fast filling on high pressure hydrogen-powered vehicles while maximizing the transferred mass and keeping the whole system safe. This solution has been industrialized and validated on several fuelling stations manufactured by Air Liquide (Figure 2).

The second and highly innovative step aims at defining adaptive control schemes for fast filling procedures. This means that control strategy should be used to refill any type of vehicle, with different tank volumes.

The final objective is to perform a filling in the most optimal way, as follows:

- Maximize the mass of product transferred within the tank
- Operate safely in regards to temperature variations
- Perform filling without communication with the vehicle (no information on type, tank volume and level)
- Operate a filling as fast as possible

Figure 2: Air Liquide hydrogen station.

To achieve this goal, a filling procedure coupled to a real-time soft–sensor has been designed and validated under simulation to estimate the temperature during a filling of the vehicle tank, after having estimated its volume and the remaining hydrogen quantity when the vehicle connects to the station.

To do so, the filling procedure starts with pulses of hydrogen being transferred into the vehicle tank.

Thermophysical assumptions, based on modelling of the tank and the station, lead to the estimation of the volume of the tank.

Based on the estimated parameters and constants, an advanced control scheme has been designed to perform the filling in regards to pre-described requirements.

This advanced control strategy is scheduled to be tested on pilot stations within the coming months.

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